QCD issues at the MC

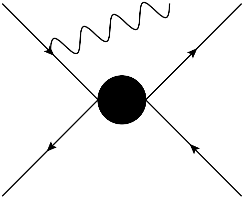
G.C. Stavenga & W. Giele

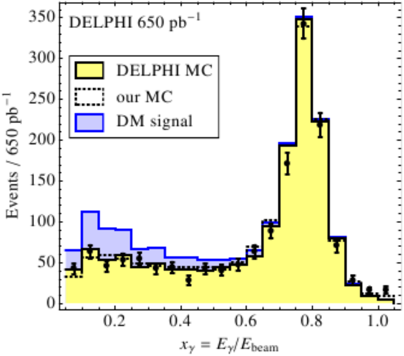
Fermilab

- Question that was raised: No need for so much as benchmarks as comparisons between ILC/CLIC and MC (maybe VLHC) for different signals.
- What are the strong/weak points of a MC.
- Focus on MC from a QCD inspired perspective

Benchmark

Let's focus on a possible benchmark of DM (gamma/Z+ME) of Patty.





Need some precission to distinguish signal from background ($\mu^+\mu^- \to \gamma\nu\bar{\nu}$).

EW logs

A $1 - 3\,TeV$ MC will give rise to Sudakov logs

- LL = $\frac{\alpha}{\pi s_w^2} \log^2(s/M_W^2) \approx 20\%$
  (see Dittmaier hep-ph/0308079)
- NLL = $\frac{3\alpha}{\pi s_w^2} \log(s/M_W^2) \approx 15\%$

even 2-loop results in 3%, so for precission calculation we need NLO EW corrections and resummations.

The cone and is MC becoming a HC?

The 10% cone prevents the detection of forward radiation. This means that the whole system gets boosted along beam axis.

Much like a hadron collider.

In case of a signal with ME and the possibility of multiple ISR in the cone we cannot reconstruct all the energies anymore.

PDF's?

We want to integrate out the forward radiation. Now we are getting a PDF for finding a muon in a muon and W in a muon. This PDF is very physical and is directly related to the cone.

This replaces $\frac{\alpha}{\pi s_w^2}\log^2(s/M_W^2) \to \frac{\alpha}{\pi s_w^2}\log^2(1/\sin^2 10) \approx 3\%$

EW jets

Now there are still large logs which coming from final states. So maybe we want to also cluster EW particles, to get rid of those.

This together with the PDF's will recast the muon collider in the familiar pdf+jets form of hadron colliders. Using this, tree level will give more accurate results

This is not a necessity (no true divergences) as in QCD, but defining observables that are safe of large logs might be a good idea.

γ/Z + ME

There is intrinsic missing energy, p_t and boosts due to ISR and cone.

We need a hard p_t and ME cut on the photon to eliminate the ISR contamination, which could hurt the signal.

A study of the ME and missing p_t. For example $\frac{d\sigma_{2j}}{d\mathrm{ME}\,dp_t^{jj}}$.

Restoration of symmetry

Within the frame work of above one can set all masses to zero.

This means one perturb around the symmetric point (Higgs vev. $v = 0$). However this should give the same results for EW safe observables upto corrections of $M_W^2/s \approx .1\%$

In such a setup one could view all particles as EW neutral Higgs boundstates. The neutrino is $\phi_i \psi_i$ while the electron is $\epsilon_{ij}\phi_i\psi_i$ boundstate. (See G. 't Hooft, www.phys.uu.nl/ thooft/gthpub/panic02.ps)

The Higgs is a tachyonic particle, but this should not pose a problem in the calculations of well defined cross sections.

MC background

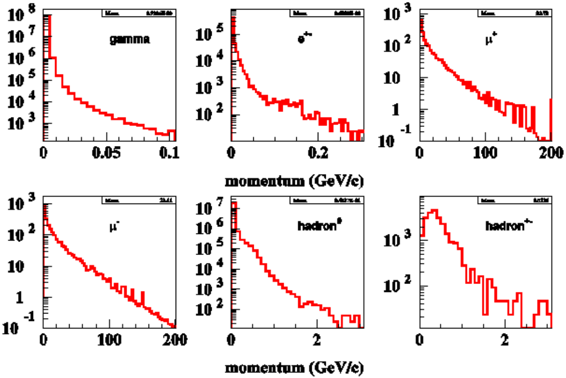


Figure: https://indico.fnal.gov/materialDisplay.py?contribId=10&sessionId=7&materialId=slides&confId=4146 (R. Lipton)

jet algorithms

What about jet algorithms? There is a lot of radiation from the halo.

We need an energy cut of $\approx 2GeV$ to get rid of the beam garbage.

This means that part of the soft radiation of QCD is not counted in the jet energy, which needs to be estimated and corrected for.

Need an (acceptable size) background files for theorist to study this and think about jet algo's in this environment.

conclusion

- if one wants to fully utilize the precission that a MC could potentially bring, one need surprisingly large order corrections in the weak coupling.
- defining appropriate observables, like in QCD, can safe you from the need to include higher order diagrams and achieve good accuracy at leading order.
- more detailed study of the appropriate PDF's is needed.
- ILC/CLIC is different because of the cone size. For ILC the EW logs are less, but for CLIC clustering with the initial beam will reduce large logs. In this sense the MC cone becomes less of an disadvantage.